DEVELOPMENTAL DYSCALCULIA AND WORKING MEMORY: IDENTIFICATION AND INTERVENTION

A
Synopsis
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SUPERVISOR
Dr.Sona Ahuja

RESEARCHER
Deepika Agarwal

HEAD
(Dept. of Pedagogical Sciences)

DEAN
Faculty of Education)

FACULTY OF EDUCATION
DAYALBAGH EDUCATIONAL INSTITUTE
(DEEMED UNIVERSITY), DAYALBAGH,
AGRA- 282005

1.0 Introduction

“Children who get off to a poor start in reading (and math) rarely catch up. We wait- they fail. But it does not have to be this way”. (Lyon et.al., 2001).

Learning disability (LD) is a general term that describes specific kinds of learning problems. A learning disability can cause a person to have trouble learning and using certain skills. The skills most often affected are reading, writing, listening, speaking, reasoning, and doing math (National Dissemination Center for Children and Youth with Disabilities [NICHCY], 2004). LD includes conditions such as perceptual disabilities, brain injury, minimal brain dysfunction, dyslexia and developmental aphasia and does not include learning problem as a result of visual, hearing, or motor abilities of mental retardation, of emotional disturbance or of environmental, cultural or economic disadvantage (IDEA, 2004).

Many people consider themselves poor in mathematics or are labeled so by others. The possible reasons could include improper teaching environment, lack of motivation, disturbing classroom environment and improper instructions (Butterworth, 2005; Wilson, 2007). If not this then is it a learning disability in mathematics or what is known as dyscalculia. The term dyscalculia is derived from Greek prefix "dys" which means "badly" and Latin "calculare", which means "to count". Thus dyscalculia means counting badly. It is presumed to be caused by a difference in brain function and/or structure, in areas of the brain involved in mathematics (Wilson, 2007). It is not reserved for individuals with low IQ or poor reading abilities. Butterworth (2003) calls it as Number blindness, a name given to the condition that affects our ability to acquire arithmetic skills. Numbers don’t seem to be meaningful to them and they are not able to intuitively grasp the size of the number and its relative value to other numbers (Butterworth, Varma & Laurillard, 2011).

The literature is riddled with different terminologies like ‘Mathematics Disorder’ Diagnostic and Statistical Manual of Mental Disorders [DSM – IV](American Psychiatric Association, 1994), ‘Specific Arithmetic Learning Difficulties’ (McLean & Hitch, 1999), ‘Mathematical Disabilities’ (Geary, Hoard & Hamson, 1999; Geary, Hamson, & Hoard, 2000), ‘Arithmetic Learning Disabilities’ (Koontz & Berch, 1996), ‘Developmental

Dyscalculia' (Shalev & Gross-Tsur, 1993, 2001) and 'Mathematical Difficulties' (Jordan, Kalpan & Hanich, 2002). These terms are used interchangeably across the literature denoting the same area of study (Price, 2008). In the present study, one of the criteria of identifying dyscalculics will be the subjects lying below the range of -1 SD (Standard Deviation) to 3 SD. For such subjects developmental dyscalculia abbreviated as DD will be used.

1.1 Developmental Dyscalculia (DD)

Developmental dyscalculia was first described by Kosc (1974) who has defined it as a difficulty in mathematics which is a result of impairment to particular parts of the brain involved in mathematical cognition, but without a general difficulty in cognitive function (as cited in Wilson, 2007). Traditional definitions e.g. DSM-IV (1994) state that a child must underachieve on a standardized test with respect to a level expected at given age, education and intelligence along with disruption to academic achievement or daily life. It refers to the difficulty in specific arithmetic skills and accounts for only a subset of individuals with arithmetic difficulties (Kaufmann et al., 2013). It is different from acalculia which is acquired late in life due to neurological injury such as stroke. According to Akenazi and Henik (2010), developmental dyscalculia is a domain specific disorder involving deficits in basic numerical processing, which are thought to be based upon neuronal impairments of key regions for numerical understanding (Kucian et al., 2013). DD is not as popular as dyslexia and frequently co-occurs with it (Butterworth, 2003). DD is a lifelong disability and occurs developmentally. Dyscalculia can be detected early in infancy as well as in adults. The best prevalence estimate for DD lies approximately in the range 3% to 10.5% as clear from Table 1.

British Dyslexia Association (n.d) has quoted some symptoms of dyscalculia which are as follow.

> **Counting**: Dyscalculic children can usually learn the sequence of counting words, but may have difficulty navigating back and forth, especially in twos and threes.
> **Calculations**: Dyscalculic children find learning and recalling number facts

difficult. They also fail to use rules and procedures to build on known facts. For example, they may know that 5+3=8, but not realise that, therefore, 3+5=8 or that 5+4=9. **Numbers with zeros**: Dyscalculic children may find it difficult to grasp that the words ten, hundred and thousand have the same relationship to each other as the numerals 10, 100 and 1000. **Measures**: Dyscalculic children often have difficulty with operations such as handling money or telling the time. They may also have problems with concepts such as speed (miles per hour) or temperature. **Direction/orientation**: Dyscalculic children may have difficulty understanding spatial orientation (including left and right) causing difficulties in following directions or with map reading.

Table 1
Prevalence Estimates for Developmental Dyscalculia

Author	Prevalence of DD in the school- aged population
Ramaa & Gowramma, 2002	5.98%
Shalev, 2004	5% to 6%
Butterworth, 2005	3.6% to 6.5%
Price, Holloway, Rasanen, Vesterinen, & Ansari, 2007	3% to 6%
Barahmand, 2008	3.76%
Vijayalaxmi, 2009	10.48%
Crespo, Valdes, Butterworth, Estevez, Rodriquez, Santos, Torres, Suarez, & Lage, 2011	3.4%
Mogasale, Patil, Patil, & Mogasale, 2012	10.5%
Jovanvic, Jovanvic, Bankovic- Gajic, Nikolic, Svetozarevic, & Ignjatovic- Ristic, 2013	3% to 6.5%

Also Dynamo Maths Programme (2014) has laid down difficulties with dyscalculic learners, some of which are listed below-

Often have difficulty counting numbers. May have difficulty processing and memorising sequences. Need extra support in counting forwards and backwards. Often have difficulties understanding place value. May find fractions confusing. May experience counting difficulties that will lead to subtraction errors. Have

> problems recording calculations on paper. Find the sequencing of time difficult. May have problems understanding the different types of averages.

National Center for Learning Disabilities (NCLD, 2006) has listed some of the areas that may be addressed while identifying dycalculic students which are as follow.

> Ability with basic math skills like counting, adding, subtracting, multiplying and dividing. Ability to predict appropriate procedures based on understanding patterns—knowing when to add, subtract, multiply, divide or do more advanced computations. Ability to organize objects in a logical way. Ability to measure—telling time, using money. Ability to estimate number quantities. Ability to self-check work and find alternate ways to solve problems.

Developmental Dyscalculia in schools is a cause of low self esteem, school dropout, and a bigger handicap in their learning process. According to Shalev (2004), treatment of dyscalculia should focus on strengthening number perception and arithmetic concepts. But to identify students with developmental dyscalculia is a major challenge. There are other reasons for a child to be weak in a given subject, stemming from external factors like motivation, teaching method, learning environment (Brody & Mills, 1997). Price and Ansari (2013) refer to the mathematical deficits arising from these external factors as secondary developmental dyscalculia. DD students seem to be born with a deficit that makes acquiring numeracy skill difficult (Butterworth, 2003). Hence appropriate measures should be taken by the researchers while identifying DD students. It is worth noting that different researchers have used different cut-off criteria for DD (Table 2) ranging from $< 10^{th}$ percentile to $< 16^{th}$ percentile due to which certain cases may be left unidentified. According to (Jordan & Montani 1997, as cited in Butterworth 2003), one can fail to diagnose dyscalculia when accuracy is considered since this will not reveal whether the subject is using immature strategies like counting on fingers. Hence diagnosing dyscalculia should be exercised cautiously.

Table 2
Selection Criteria for Developmental Dyscalculia

Author	**Criteria**
Butterworth, 2003	Bottom 2 stanines (lowest 11% of the score) on Dyscalculia Screener
Landerl, Bevan, & Butterworth, 2004	3 SD below the mean on Item- timed arithmetic and teacher's classification
Rosselli, Matute, Pinto, Ardila, 2006	2 SD below the mean on Wide Range Ability Test (WRAT)
Price, 2008	At least lower 10^{th} percentile or 1.5 SD below the control mean on- (Rasanen) Mathematical Achievement Test (RMAT)
Moeller, Neuberger, Kaufmann, Landerl & Nuerk, 2009	>1 SD below age norm on the subtests of the subscale arithmetic operations of the Heidelberger Rechentest (HRT)
Gilga & Gilga, 2011	2 SD from the mean value on Screening Test
Wang, Tang, & Yang, 2012	Below 15^{th} percentile on Fundamental Mathematical Concepts Assessment
Szucs, Devine, Soltesz, Nobes, & Gabriel, 2013	-1 SD or $< 16^{th}$ percentile on Mathematics Assessment for Learning and Teaching (Malt) and Numerical Operation subtest of Wechsler Individual Achievement Test (WIAT-II)

Also, Askenazi and Henik (2010) have reported that developmental dyscalculia is related to deficits in areas like attention, working memory and long term memory. The next section underlines the conceptual framework of working memory.

1.2 Working Memory

In our everyday lives we need to store certain bits of information like remembering a phone number between the time of hearing, dialing it or holding driving directions in mind till we finally reach our destination. All these tasks require working memory which corresponds to the RAM of the computer. Thus one can think of it in terms of a mental blackboard that allows for temporary storage of information and is highly accessible for inspection and computation. Working Memory is defined as "a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning and reasoning." (Baddeley, 1992,

p.556). Many models of working memory have been proposed by different researchers but the multiple component working memory model, Baddeley and Hitch (1974) model still remains the most influential framework in this area (Landeira–Fernandez, Zylbergberg-Landeira, Charchat-Fichman, Cardenas, 2012). It comprises of three components- phonological loop, visuo-spatial sketch pad and central executive. Baddeley (2000) proposed a fourth component the episodic buffer. Each of these components of working memory has specific functions. The phonological loop for passive storage of verbal information, visuo-spatial sketchpad for passive storage of visuo-spatial information (Baddeley & Hitch,1974, as cited in Mita, 2013), central executive controls the flow of information between the phonological loop and the visuo-spatial sketchpad and temporary activation of long term memory(Alloway, 2008). The episodic buffer comprises a limited capacity temporary storage system, capable of binding information from the subsidiary systems, and from long-term memory, into a unitary episodic representation (Baddeley, 2000). Figure 1 illustrates Baddeley (2000) multiple component working memory model depicting all the four components.

Further, the fact that there is a domain general component for processing information along with two domain specific components for the temporary storage of verbal and visuo-spatial information has been supported in studies of children (Alloway, Gathercole, & Pickering, 2006; Bayliss, Jarrold, Gunn, & Baddeley, 2003), adult participants (Kane et al., 2004) and neuro- imaging research (Jonides, Lacey, & Nee, 2005). Alloway et al (2006) found that the processing aspect of both verbal and visuo-spatial working memory tasks was controlled by a centralized component- central executive while the short term storage aspect was supported by a domain specific component- the phonological loop for verbal information and visuo-spatial sketchpad for visuo-spatial information. According to Nobre (2013), the tasks for the assessment of the episodic buffer are still being developed and Baddeley (2012) is of the opinion that measurement of the episodic buffer is an unresolved problem.

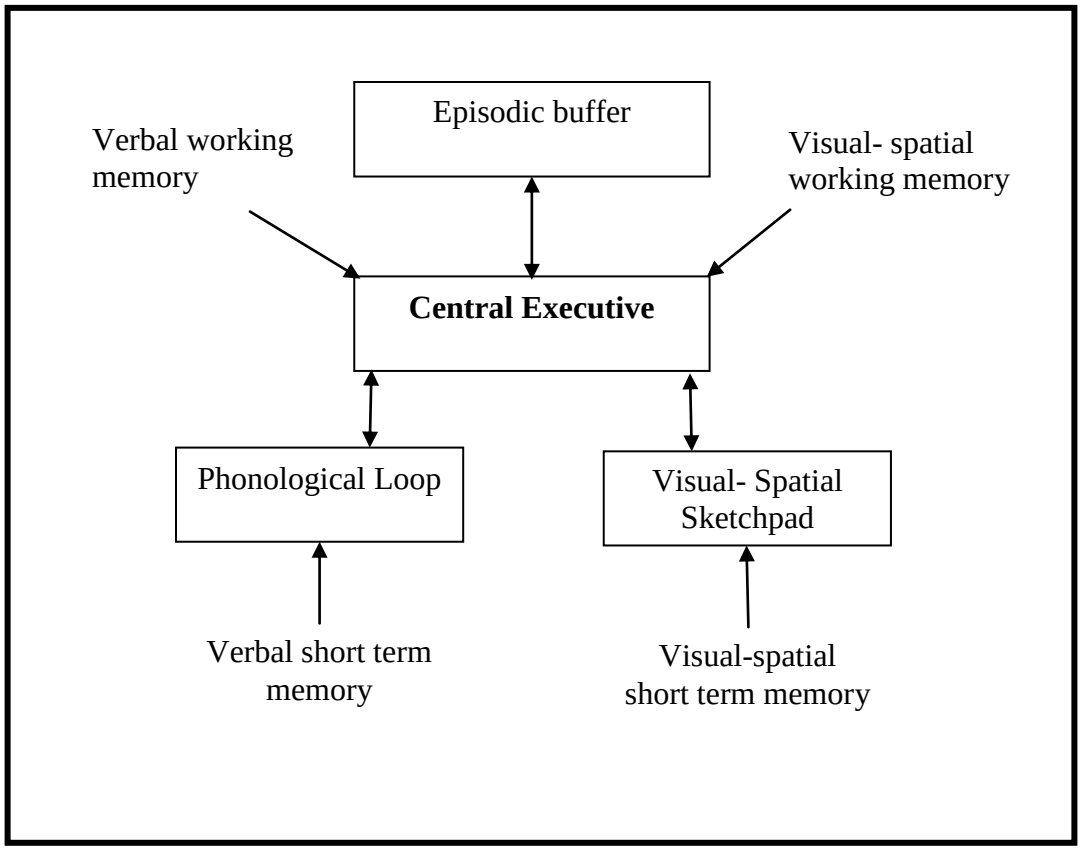

Figure 1: Baddeley's Multi-Component Model of Working Memory (2000). Adapted from "The Identification of Language Impairment in English Additional Language Learners" by H.M. Marshall, 2013, Master's thesis.

1.3 Working Memory and Mathematics

Working memory plays a very important role in mathematics. For instance, for adding two numbers mentally, requires initially storing the problem in the working memory before a solution can be found. Raghubar, Barnes and Hecht (2010) is of the view that while solving mathematical problem, working memory is required to hold partial information, process new information, and ignore irrelevant information. Studies like Swanson and Beebe-Frankenberger (2004) have shown strong relationship (correlation of 0.54) between working memory and mathematical problem solving.

Alloway, Gathercole, kirkwood and Elliot (2009) have suggested the children with low working memory experience difficulties in school related to learning like distractibility, problems generating new solutions, and monitoring the quality of work and in particular subjects including mathematics. Also research results indicate that working memory

components are associated with mathematical performance (Bos, Ven, Kroesbergen & Luit, 2013). Low working memory scores have been found to be closely related to poor computational skills (Wilson and Swanson, 2001, as cited in Alloway 2006). Further Andersson and Lyxell (2007) found that children with mathematical difficulties have a working memory deficit. Hence from the aforesaid evidences it is clear that working memory problem may lead to poor mathematical skills. Since DD is a difficulty in acquiring arithmetic skills and is therefore related to poor working memory.

Given the effect of working memory impairments on mathematics, developmental dyscalculia and more, the working memory performance of such students need to be improved to meet the heavy demands of the classroom learning in general.

2.0 Emergence of the Problem

There are many learners who are not able to perform in mathematics. But some students are unable to perform even simple arithmetic tasks and their problem range from understanding the basic concepts of numbers to addition, subtraction or multiplication. There are learners who are frustrated because they cannot understand numbers and give hope to learn the same. They don't know whether it is a problem in teaching, lack of interest in the subject or is it developmental dyscalculia they are suffering from. Butterworth (2003) has talked about one such DD student Charles (age 31), who even with a degree in psychology was unable to multiply two one digit numbers or add or subtract two digit numbers. Another case Tania (age 9), who was less confident in counting backwards and had difficulty in interpreting the subtraction sign (Gifford & Rockliffe, 2008). Such children are often left undiagnosed and untreated may be forever which make them more liable to be ripped off. Butterworth et al. (2011) have reported that much lesser funds are available to researches on dyscalculia as compared to dyslexia. However, the problem of developmental dyscalculia is acute. Can there be some tool to reliably identify DD students? Is it possible to help them if not to solve it completely? What kind of remedy can be given to these students? These questions and more perturbed the researcher. The researcher did not come across any study that may give satisfactory answers to these questions. Hence the present study is conducted with justification in the succeeding section.

3.0 Justification of the Problem

Developmental dyscalculia is a congenital and specific learning disability in understanding numerical concepts (Cappelleti & Price, 2014). Wilson and Dehaene (2007) concluded that there is a core deficit of number sense in dyscalculia. Akin to dyslexia, researches on DD are now receiving increasing attention. A *PsychInfo* search for peer-reviewed articles reveals 31 papers published from 1991–2001, versus 74 papers published from 2002–2012 but still it is less researched as compared to dyslexia (Kaufmann et al, 2013). According to Gulliemot (2001) the main reason as to why research on dyscalculia is conducted is hopefully to give remedy to a person with mathematics learning disability. Diagnosis at an early stage will not only increase their confidence level but will also help them to develop a positive attitude towards the subject.

The Basic Skills Agency (as cited in Butterworth, 2003) also reports that poor numeracy is a bigger handicap in getting a job. The Organization for Economic Co-operation and Development (OECD, 2010) demonstrated that "an improvement of one-half standard deviation in mathematics and science performance at the individual level implies, by historical experience, an increase in annual growth rates of GDP per capita of 0.87%" (p.17) . If DD students are not recognized then this can prove to be major setback in their future careers. Unless specifically treated, dyscalculia persists into adulthood (Kaufmann, Pixner & Goebel, 2011; Butterworth et al., 2011).

The major problem is the identification of DD students. Further from Table 2 it is clear that a wide variety of test have been used by researchers to identify DD students but there is no consensus among the researchers. According to Denes and Goswami (2013), different standardized test may not measure the same kind of skills supporting mathematics. Different tests of DD measure different parameters (Table 3). Moreover, when the assessments rely on a composite score it may run the risk of failing to identify such cases as dyscalculic (Kaufmann et al., 2013). Further, research studies also report the use of screeners, for instance Dyscalculia Screener (2003) developed by Brian Butterworth, the most widely used screener to identify DD students, however lacks in fulfilling the psychometric properties (reliability and validity of the tool).

Table 3
Parameters used to Identify DD Students

Author	**Test**	**Parameters**
Butterworth, 2003	Item –timed tests of enumeration and Number Comparison	Simple Reaction Time, Tests of Capacity (Dot Enumeration and Number Comparison) and Test of Achievement (addition and multiplication)
Attwood & Team	Testing for Dyscalculia and the On-Line Dyscalculia Test	Decimals, directions, Bar Graph, and Interval Bisection and Towards Abstraction
Price, 2008	RMAT test of Arithmetic Achievement	Single and Multi digit addition, Subtraction, Multiplication and Division, Decimal Conversions, Fraction Calculations and Simple Algebra
Beygi, Padakannaya & Gowramaa, 2010	Key math Diagnostic Arithmetic Test	Basic concepts (numeration, rational numbers, geometry), fundamental arithmetic operations (addition, subtraction, multiplication, division, mental computation), applications (measurement, time and money, estimation and problem solving)
Gilga & Gilga, 2011	The Screening Test	Approximating Numbers, Identification of Small Quantities, Subitizing, Numerosity Coding , Use of Mathematical Language
Purohit & Margaj, 2012	Questionnaire and Computer Assisted Friendly Instruction	Shape Recognition tests, Size Discrimination, Sets and Numbers, Counting, Auditory-Visual Association, Place Value and Arithmetic Tests
Cangoz, Altun, Olkun, & Kacar, 2013	Computer Based Screening Dyscalculia	Dot Counting, Number Comparison, Perceptual Quantity Estimation, Number Line Estimation and Simple Arithmetic

The present study expands in the direction of overcoming the aforesaid limitations of diagnosing developmental dyscalculia and to evolve a better strategy to identify DD students. However, the diagnoses of developmental dyscalculia do not suffice the objective until they are helped for problems of working memory, attention, inhibition and more.

The different cognitive functions (working memory, attention, inhibition etc) seem to play an important role in mathematics and hence can be plausibly related to DD, mostly been neglected by neuro-imaging research (Szucs & Goswami, 2013). A number of

studies have found working memory impairments in DD students among school aged population. Also different studies have found different components of working memory impaired in DD students (Table 4).

Table 4
Working Memory Impairments in DD Students

Author	Problem Area
Swanson & Beebe- Frankenberger, 2004	Verbal Working Memory
Sluis , Leij, & Jong, 2005	Visuo-spatial Working Memory
Rosselli et al, 2006	Verbal Working Memory
Kyttala, 2008	Visuo-spatial Working Memory
Geary, Bailey, Littlefield, Wood, Hoard, & Nugent, 2009	Verbal and Visuo-spatial Short Term Memory, Verbal Working Memory
Passulungi & Mammarella, 2011	Spatial Working Memory
Swanson, 2012	Verbal Short Term Memory and Verbal and Visuo-spatial Working Memroy
Szucs et al., 2013	Visuo-spatial Short Term Memory and Visuo-spatial Working Memory

Furthermore, most of the studies (Beygi et at., 2010; Wilson, Dehaene, Pinel, Revkin, Cohen, & Cohen, 2006; Butterworth & Laurillard, 2010; Kucian et al., 2011) have focused on providing interventions with respect to arithmetical skills. Szucs et al., (2013) have reported that the intervention studies should explore whether working memory impairments can be improved in DD students. Further, training in working memory has improved numeracy skills (Kroesbergen & Noordende, 2014). Researcher did not come across any study that has dealt with providing interventions for working memory impairments to DD students. The consequences of working memory impairments in DD students can be detrimental and thus it is essential for the researchers to direct their efforts in providing appropriate intervention for working memory to such students which is one of the objectives of the present research study.

4.0 Statement of the Problem

The research problem can be stated as below:

A Study of Effect of Working Memory on Developmental Dyscalculia.

5.0 Variables of the Study

Independent Variable: Working Memory

Dependent Variable: Developmental Dyscalculia

6.0 Objectives of the Study

The purpose of the study is five fold:

1. To determine the parameters on which diagnostic test to identify DD students will be based.
2. To identify the students with developmental dyscalculia.
3. To determine the working memory components impaired in identified DD students.
4. To study the effectiveness of intervention for working memory impairments on DD students.
5. To examine the effect of intervention for working memory impairments on developmental dyscalculia.

7.0 Hypothesis

1. There will be no significant improvement in the working memory of students with developmental dyscalculia post intervention.
2. There will be no significant effect of intervention for working memory impairment on developmental dyscalculia.

8.0 Delimitations of the Study

The study will be delimited to Agra city only.

The study will delimited to students in the age range 8-12 years.

9.0 Operational Definition of the Terms

Developmental Dyscalculia

The Department of Education and Skills (DfES, 2001) defines dyscalculia as

> Dyscalculia is a condition that affects the ability to acquire arithmetical skills. Dyscalculic learners may have difficulty understanding simple number concepts, lack an intuitive grasp of numbers, and have problems learning number facts and procedures. Even if they produce a correct answer or use a correct method, they may do so mechanically and without confidence (p. 2).

Working Memory

Functional Definition

Baddeley & Logie (1999) defined working memory as "moment-to-moment monitoring, processing and maintenance of information" (p.28).

Operational Definition

Gathercole and Alloway (2004) defined working memory as the ability to hold and manipulate information in the mind for a short period of time. It provides a flexible mental workspace that is used in many important activities in everyday life.

In the present study to assess the working memory of the DD students the following working memory components will be considered:

1. Verbal short term memory which will provide measure for the phonological loop component.
2. Visuo-spatial short term memory which will provide measure for the visuo-spatial sketchpad component.
3. Verbal working memory and Visuo-spatial working memory which will provide measure for the central executive component.

10.0 Design of the study

The research design for the present study is as follow.

10.1 Sampling Procedure

Figure 2 depicts the selection of the sample.

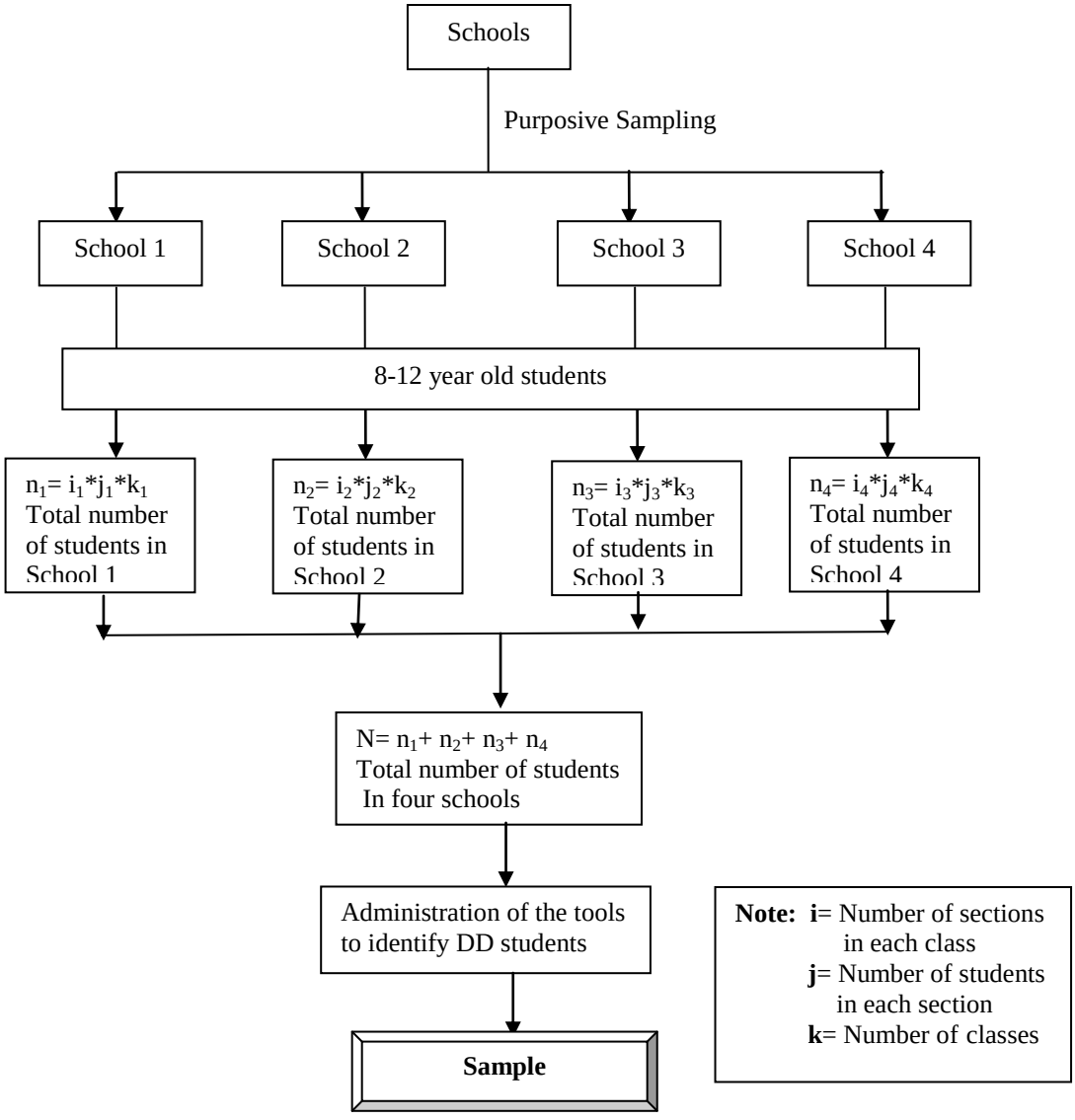
Schools
Purposive Sampling
School 1
School 2
School 3
School 4
8-12 year old students
$n_1= i_1*j_1*k_1$ Total number of students in School 1
$n_2= i_2*j_2*k_2$ Total number of students in School 2
$n_3= i_3*j_3*k_3$ Total number of students in School 3
$n_4= i_4*j_4*k_4$ Total number of students in School 4
$N= n_1+ n_2+ n_3+ n_4$ Total number of students In four schools
Administration of the tools to identify DD students
Sample
Note: i= Number of sections in each class
j= Number of students in each section
k= Number of classes

Figure 2. Procedure of sample selection.

Four schools will be selected through purposive sampling. Students in the range 8-12 years will be considered from each section of respective classes for selected schools. In the next step, tools will be administered on all these students to get the desired sample of DD students. According to Sadock, Sadock & Kaplan (2009), a child with mathematics disorder can usually be identified at the age of 8 years. Hence in the present study students of 8 years and above are considered.

10.1 Method of the Study

The present research will be quasi-experimental with matching-only pretest-posttest control group design. It is proposed that the subjects in each group will be matched on Age, IQ and Reading Ability. The letter M in Figure 3 denotes that the matching of subjects on the aforesaid variables.

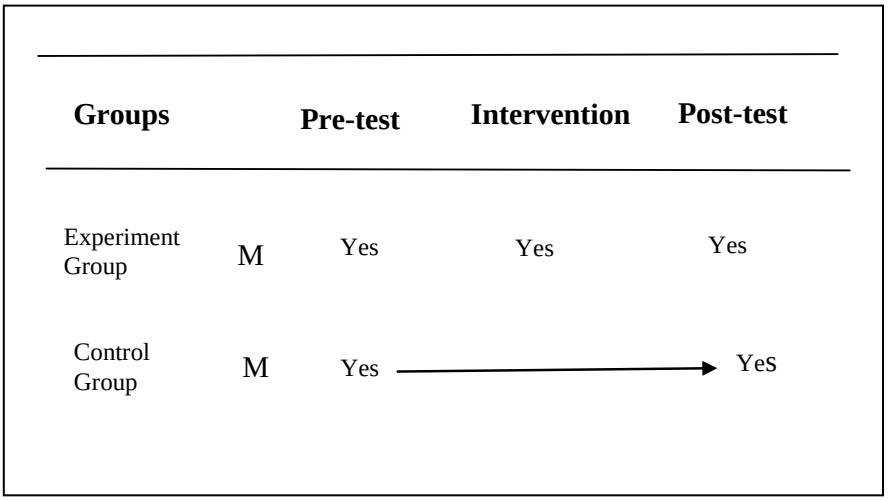

Figure 3. Design of the study.

10.2 Tools

The following research instruments will be constructed by the researcher for the fulfillment of the proposed objectives in the present study-

Diagnostic Test to Identify Students with Developmental Dyscalculia

Many successful screeners are developed by experts to identify DD students (Dyscalculia Screener, Butterworth, 2003; The Screening Test, Gilga & Gilga, 2011). But these

screeners do not have an open access, are not economical and lack in reporting of reliability and validity. Further in Dyscalculia Forum (2014), a DD student NumericallyConfusedBatman (age 17) has shared his views regarding his trouble with numbers. He is interested in getting officially tested for DD but even the most reasonable test would charge $100 to $200 (Dycalculia Forum, 2014). Also several others studies have used standardized tests (Fundamental Mathematical Concepts Assessment, Wang et al, 2012, A Mathematical Achievement Test (RMAT), Price, 2008) to identify DD students. Such tests include the kind of arithmetical problems taught in schools and many other pupils will also manifest poor attainment apart from DD students (Butterworth, 2003). Hence the present research study aims to develop a self constructed diagnostic test to identify DD students and probably help in diagnosing DD in the near future.

For its construction the researcher will make use of Nominal Group Technique (NGT); a brain storming technique to get consensus of various experts over the parameters on which the diagnostic test will be based.

Reading Ability test

A reading ability test will be constructed by the researcher to measure the performance of the students in the range 8-12 years. It will contain items like reading of words, sentences and more.

Intelligence Quotient

To measure the IQ of the students, Wechsler Intelligence Scale for Children (WISC-III, 1991) will be used. The test-retest coefficients for verbal IQ and performance IQ are 0.94 and 0.87 respectively. Also the tool has construct and criterion validity.

Working Memory Tool to Assess the Working Memory of Students with Developmental Dyscalculia

The most widely used tools to assess the working memory of the students with developmental dyscalculia are Automated Working Memory Tool (AWMA, 2007) by Alloway and Working Memory Test Battery for Children (WMTB-C, 2001) by Gathercole and Pickering. WMTB-C does not include the measures for visuo-spatial

working memory so this tool is not considered in the present study. AWMA on the other hand also includes three visuo-spatial working memory measures, making it a comprehensive one. But AWMA being costly (approx Rs 25000), a self constructed tool will be used to assess the working memory along with one component from WISC – III viz Digit Span.

AWMA has satisfactory reliability and validity. The reliability of the tool is provided in Table 5 and has convergent and divergent validity.

Table 5
Reliability of AWMA Tool

Tests	**Test-retest reliability coefficients**
Verbal complex memory	
Backwards digit recall	.64
Listening recall .81	.81
Counting recall	.79
Visuo-spatial complex memory	
Odd-one-out	.81
Mr. X	.77
Spatial span	.82
Verbal short-term memory	
Digit recall	.84
Word recall	.76
Nonword recall	.64
Visuo-spatial short-term memory	
Block recall	.83
Mazes memory	.81
Dot matrix	.83

Mathematical Ability Test

The researcher will construct a Mathematical Ability Test suitable for the selected range to measure the general mathematical ability of the students in the age range 8-12 years. It will contain items like word problems, basic addition and subtraction and more.

10.3 Procedure of the Study

The present study will be carried out in the following stages-

Stage 1: **Construction of the Tools**

In this stage, to identify the students with Developmental Dyscalculia, the researcher will construct the following tools-

1. A Diagnostic test to identify students with developmental dyscalculia.
2. A Mathematical Ability Test to measure the mathematical ability of the students.
3. A Reading Ability Test to measure the reading ability of the students

Stage 2: **Identification of Students with Developmental Dyscalculia**

Convergent measures will be used to identify students with developmental dyscalculia. This stage will comprise of steps as follow-

1. Researcher will collect the marks of the all the students in the age range 8-12 years in the subject mathematics from their previous school records. Students who have achieved marks less than 70 will be considered further in the study.
2. In this step concept of DD as underlined in the researches will be discussed with the teachers in order to sought correct data from them.
3. Students who have achieved marks greater or equal to 70 in the mathematics subject, teacher's interview will be conducted so as to know if any of these students faced some kind of difficulty in solving mathematical problems for e.g. using immature strategies to solve arithmetical problems or taking longer time to solve simpler problems. Such identified students will also be considered further in the study.
4. On the selected sample of students, a mathematical ability test will be administered. This will be done to filter out those students who are weak in mathematics because of disturbing environment, improper teaching, lack of motivation etc.
5. On this remaining sample two test viz reading ability test and an IQ test will be administered. This will be done to ensure that the selected sample does not have poor reading ability and also low IQ when dealing with working memory in DD students (Landerl, Bevan, & Butterworth, 2004).

6. On this final sample of students, a self constructed diagnostic test will be administered. Based on the score of this tool, the students selected will be designated as having developmental dyscalculia.

Stage 3: **Construction of Working Memory Tool**

In the advent of the non availability of the Automated Working Memory Assessment (AWMA, 2007) by Alloway, a self constructed tool will be employed to tap the three components –phonological loop, visuo-spatial sketchpad and central executive. This will include measures for verbal short term memory, verbal working memory, visuo-spatial short term memory and visuo- spatial working memory components based on AWMA tool to assess the working memory of the children with developmental dyscalculia along with one component from WISC – III viz Digit Span.

Stage 4: Administration of the Working Memory Tool

Working Memory tool will be administered to identify the components of working memory which are impaired in students with developmental dyscalculia.

Stage 5: **Development of Intervention Program for Working Memory Impairments**

An intervention program will be developed for those components of working memory where the students with developmental dyscalculia are found to be impaired. This will be done directly by making students practice on working memory tasks like digit span, counting recall, block recall etc.

Stage 6: **Intervention for Working Memory Impairments**

This stage will involve providing intervention for working memory impairments. The duration of providing intervention for working memory impairments will depend on the number of components of working memory found to be impaired. For example, the intervention for central executive component of working memory will include practicing backward digit recall task, counting recall task (Witt, 2011).

Stage 7: **Testing of Hypothesis**

This stage will comprise of the testing of hypothesis on the scores obtained from pre-test and post- test.

10.4 Statistical Techniques

The following statistical techniques will be employed in the present study

Descriptive statistics: Mean, Standard Deviation

Inferential Statistics: t-test will be used to-

1. Determine the effectiveness of intervention for working memory impairments on DD students.
2. Determine the effect of intervention for working memory impairments on developmental dyscalculia.

11.0 Significance of the Study

In a numerate society it is very important to have an optimum level of number knowledge to survive in the modern workplace. There is an urgent need to identify DD students so that they can be helped timely. Contemporary researches on DD are working in this direction with promising results. By conducting research in this field will not only provide an understanding of number concepts which DD students lack but will also shed light on the teaching interventions appropriate for them. It will also bring awareness among educationists, parents, administrators to understand their needs and implement strategies that may help them to acquire basic arithmetic skills if not complex mathematics.

Until now, researchers have focused mainly on interventions related to arithmetical concepts but role of cognitive functions cannot be neglected. The current research study intends to bring the importance of one of the cognitive function working memory. If we are able to enhance working memory processes of DD students, we can say that to some extent it will have a positive effect on developmental dyscalculia also. Thus we hope that this short communication will provide a productive way forward to help DD students and adults (who were left undiagnosed) as a means of removing obstacles from their path of progress.

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